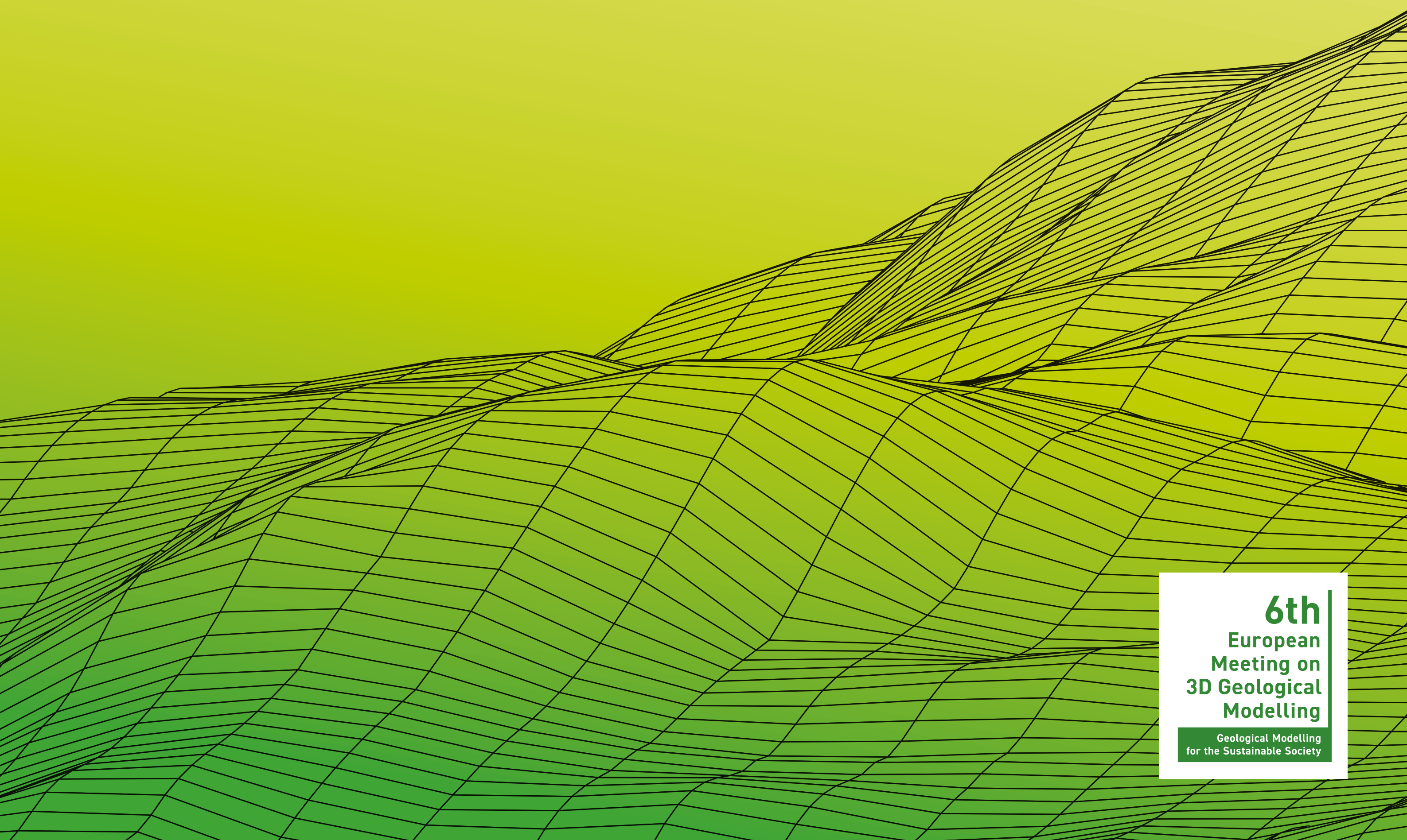
CONTRIBUTIONS TO THE 6TH EUROPEAN MEETING ON 3D GEOLOGICAL MODELLING

ABSTRACTS



6th European Meeting on 3D Geological Modelling

Geological Modelling for the Sustainable Society

SESSION 1: GEOMODELLING OF THE NEAR-SURFACE – TOWARDS A SUSTAINABLE SOCIETY

Geological modelling of the near-surface is used for a wide variety of purposes related to the development of a sustainable society, e.g., planning and protection of groundwater resources, climate adaption, mapping of raw materials and critical minerals, etc. The modelling projects vary greatly in scale and necessary degree of detail and the required modelling methods are therefore manifold. This session is targeted presentations concerning the use of near-surface geological models for sustainability.

GEOLOGICAL 3D MODELLING IN URBAN AREAS – A WORKFLOW FOR UTILIZING LARGE GROUND INVESTIGATION DATASETS

Kosonen. E., Hornborg, N. Lindqvist, T, Putkinen, N., Ahlqvist, K.

In recent years, Geological Survey of Finland (GTK) has developed different tools to convert and exploit geotechnical investigation datasets in different modelling platforms to enable local and regional scale bedrock surface and superficial deposits 3D modelling in urban areas. While working with third parties' (cities), it is often the case that large and heterogeneous datasets cannot be individually checked. For this reason, it has been essential to create workflows to harmonize, possible reclassify and simplify lithology according to purpose-built conceptual models.

In this presentation we are going to demonstrate the results of years of development work highlighting the latest achievements in the SEISMIC RISK -project. The project studies on how to mitigate induced seismic risk associated with deep geothermal power stations in the Helsinki capital region, Finland. In this project we have focused on generating harmonized large datasets of geological, geotechnical and crystalline bedrock structural properties of the subsurface environment for the capital region area and building a 3D geological model covering the continuous onshore-offshore area of the Helsinki capital region in total of 770 km2 (cities Helsinki, Espoo, Vantaa). In the project, significant attention has been put into the reliability of the geological models starting from bedrock surface topography modelling development by structural geology studies. Reducing the uncertainty of the bedrock surface modelling will lead on attaining reliable sediment properties and thicknesses. One of the main aims of the 3D model deliverables is to be utilized as test platforms for assessing induced seismic risk in Helsinki capitol region. This will be tested with thematic 2D maps, that will be made based on subsurface sediment parameters and thicknesses (seismic classification) with multivariate analysis in GIS environment based on dense synthetic borehole generation from the numerical 3D data. The units' characteristics and boundaries were chosen for the possible inverted use of geotechnical purposes for city planners and other end-users.

Acknowledgements

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UK URBAN SUBSURFACE RESEARCH – WHERE NOW AND WHERE TOO

Ricky Terrington

The British Geological Survey (BGS) has been a world leader in urban 3D geological modelling. This reputation was largely developed through the Glasgow and London cross cutting projects and led to follow-up high profile international 3D geological modelling collaborations in Europe (Horizon 2020 COST SubUrban Action), the Middle East (Abu Dhabi) and Asia (Singapore).

Urban 3D geological data and information has been leveraged for use across many types of projects, such as tunnelling and construction, shallow geothermal energy systems and geohazards, such as the shrinking and swelling of clays rich environments, a cause of subsidence. However, there are opportunities to better understand the urban subsurface and how we interact with the data and information provided.

For example, anthropogenic deposits, including their make-up and depth, are often poorly understood in urban areas. Artificially modified ground can mimic naturally occurring deposits as they have a lithogical variation akin to natural deposits albeit at more localised scale. Similarly, the geotechnical and hydrogeological properties of the urban subsurface will be affected by the anthropogenic deposits (up to 20m below ground level. Infrastructure such basements and tunnels can also impact the future use of the resource available in the subsurface. The risk being that some resource (geothermal energy or mineral resources) may become sterilised because of unmanaged development of the near surface urban environments. The convergence of Digital Twin and smart city technologies can provide a key role in the interaction and understanding of geological data (including real-time telemetric data) with the built environment, including subsurface artificial structures and artificially modified ground. Providing a virtual decision information system in one immersive space will be key to analysis, understanding and choosing the optimal option.

In this presentation we will look at some recent examples from the BGS (including eternal collaborations) in urban subsurface 3D investigations, and a look at where further research is required.

NEAR SURFACE 3D-MODELLING IN URBAN AREAS – APPROACHES AND OUTCOMES

Rouwen Lehné

For the last 15-20 years, 3D geological modeling has been gaining increasing importance in the geological services. In the meantime for almost all federal states in Germany, so-called state models are available, which can be linked to geological overview maps at scales of 1:200,000 - 1:500,000 in terms of their level of detail. While these models were initially mainly stratigraphic models (modeling of layer boundaries), volume models have increasingly been created over the last few years, which are usually related to a specific topic and/or project. Thus, especially the deep geothermal potential was considered. In the further evolution of geological 3D modeling, medium-depth and near-surface issues were then also taken up in greater detail with the help of parameterized volume models (e.g. groundwater, geothermal energy and subsoil, the latter especially in urban areas).

Since 2016, one of the focal points of the 3D modeling work at the HLNUG has also been in urban areas, where an integrated approach is now being pursued instead of isolated geological modeling, as has been practiced up to this point (and still ist practiced mostly). The overall objective here is focused on the creation of digital 3D information systems for cross-institutional integration and browser-based functional visualization and provision of different kinds of 2D/3D data. As a result, important geological information on the approx. upper 100 m will be made available in a simpler and better-performing way for municipal duties and workflows given in government agencies. The aim is to improve interoperability with existing production environments for 3D city models and to make them available via existing portals (e.g. geoportals) so that they can be viewed together with other 2D/3D data (e.g. groundwater, technical infrastructure such as gas and water supplies and sewers). Within the scope of the presentation, approaches for modeling, parameterization and the interpolation of parameters in the 3D volume for the near-surface area of the cities Darmstadt and Kassel as well as first results will be presented.

ANTWERP'S SHALLOW SUBSURFACE: UNLOCKING ITS POTENTIAL FOR A SUSTAINABLE FUTURE THROUGH DETAILED GEOLOGICAL STUDY AND VOXEL MODELING.

Van Haren T., Deckers J., De Koninck R., Dirix K.

The urban subsurface offers many opportunities in addressing challenges like sustainable energy supply, groundwater management, utilization of underground space, raw materials and climate adaptation. However, to map its full potential, a deep understanding of the shallow urban subsurface is necessary. In Antwerp (Flanders, Belgium), major infrastructure works are planned at its port and the urban periphery in the near future. Therefore, the Flemish government has ordered VITO to model the local shallow subsurface. The project is being guided by a stakeholder-consortium consisting of different government agencies related to environment, geotechnical research, mobility and public works. During the project, interaction with on-site tests was monitored offering the opportunity to discuss data and geological insights to be incorporated in the model, and to exchange samples of the site investigations for preservation by the government on the long term. The government's primary goal was to examine the degree of detail in which the shallow subsurface can be mapped to gain a better understanding of the types of sediments and their properties that can be expected during major infrastructural works in the near future, including the delineation of the anthropogenic with in-situ sediments. On the other hand, the government wants to raise the awareness of the subsurface by publishing the 3D model in an easily accessible 2D Viewer (https://www.dov.vlaanderen.be/portaal/?module=ondiepmodelantwerpenverkenner).

The city-scale model of Antwerp is a test case for other urban areas in Flanders. The model is highly detailed, based on the interpretation of thousands of boreholes and cone penetration tests (CPTs) and outcrop studies. In particular the interpretation of CPTs has added detail to the model. The model shows the expected spatial distribution and thickness variation of the Boom Clay, the Neogene sands, the Pleistocene, Holocene and an indication of the anthropogenic deposits.

To construct the model, existing boreholes and CPTs managed in the regional Flanders Soil and Subsoil Database (DOV) were lithostratigraphically interpreted, coded and converted into different voxel parameters. The model consists of more than 21 million voxels with dimensions of 25 x 25 x 0.5 m and extends to a depth of 50m below sea level. Lithofractions have been assigned (shares of peat, clay, silt, fine sand, medium sand, coarse sand, and gravel) by 3D-interpolation using software program Rockworks®. The voxel model also includes information about expected glauconite content, presence of shell admixtures, carbonate content, bedrock and concretions for every lithostratigraphical unit.

The model is since 2022 available online as a prospective instrument for geological, geotechnical, and hydrogeological applications or research for the Antwerp region.

NORWAY'S POTENTIAL IN REE – MODELLING THE FEN CARBONATITE COMPLEX

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Sven Dahlgren (Geological Advisor, Vestfold and Telemark County Council, Tønsberg, Norway and Njord Center - Physics of Geological Processes, Department of Geosciences, University of Oslo, Norway)

The Fen Complex is a carbonatite and alkaline complex, emplaced around 580 million years ago in Mesoproterozoic orthogneisses in Southern Norway. It is located about 110 km southwest of Oslo at lake Norsjø in the Telemark County. With a circular shape of about 4-5 km2 it most likely represents the roots of an eroded volcano.

Carbonatite and alkaline intrusive rocks are the primary source of Rare Earth Elements (REE). These are metals of fundamental importance for hi-tech applications and the production and storage of renewable energies. Worldwide only a handful of REE deposits are in production while none of the few European deposits is among them. Consequently, Europe is entirely dependent on the import of raw materials that are critical for industry and society. Preliminary estimates suggest that the Fen Complex may contain at least 50 million tons of REE-oxides, and if validated and exploitable this deposit would have international importance (Dahlgren 2019).

Due to a prominent density contrast between the intrusion and its surrounding rocks, gravity data is an important asset to study the Fen Complex. Based on 2D and 2.5D modelling, two different models were previously proposed. One suggests a cylindrical, vertical, downward extension of the complex, where the carbonatites constitute only the uppermost 0.5-1 km with denser, cumulate rocks below. A second model suggests a south-westward-dipping pipe of carbonatites with a core of denser rock.

Because of increased interest and the possible importance of the deposit, investigations in the Fen area have been intensified over recent years. Geophysical data were collected during several campaigns to aid in mapping and modelling. The data include district-scale airborne magnetic and radiometric data, as well as ground gravity data. The new gravity data include in addition two high resolution profiles crossing the centre of the intrusion. Two vertical boreholes were drilled at the gravity high, revealing that the REE-bearing carbonatites continue at least 1 km downward. Petrophysical analysis was carried out on drill core and field samples to further aid prospect-scale modelling.

The new data compilation, together with bedrock maps and field observations, builds the basis for the 3D modelling that was now used to gain a better understanding of the intrusion complex. Geophysical and geological modelling was combined in an integrated approach. Geophysical modelling on a district-scale took the lead, as the depth extent of the intrusion was a main target of the investigations. It was supplemented and refined in a geological modelling environment. Combining both disciplines adds constraints and geological meaning to the geophysics, making the model less abstract. On the other hand, the geological model benefits from depth information and surface patterns revealed by geophysics. The final model satisfies data and observations from both disciplines and gives a holistic representation of the subsurface.

APPLICATION OF RANDOM FOREST MACHINE LEARNING FOR REGIONAL 3D HYDROSTRATIGRAPHIC MODELING

Jesse T. Korus, Tewodros Tilahun

3D hydrostratigraphic models are important for groundwater planning, management, and modeling. At regional scales, such models benefit from the inclusion of airborne electromagnetic (AEM) surveys because they provide dense resistivity-depth models that fill gaps between boreholes. But the resistivity-lithology relationship is nonunique and nonlinear, so transforming resistivity into hydrostratigraphy is not straightforward. We use random forest-based machine learning to learn the relationship between resistivity and hydrostratigraphy and then predict the 3D distribution of hydrostratigraphic units. The method uses numerous lithological terms from thousands of boreholes, which are grouped into 5 hydrostratigraphic units based on hydrologic characteristics, grain size, texture, and assumed resistivity characteristics. The input data are resampled into a 200x200x1m grid and then the hydrostratigraphic units are paired with co-located resistivity nodes. The data pairs are split into 70% training and 30% validation. Initial results show that hydrostratigraphic unit prediction had a training F1 score of 97% and 91% testing accuracy, improving to 100% and 95% after hyperparameter tuning. This method is fast and reproducible. It creates high-resolution 3D models of hydrostratigraphic units that can be used to build robust frameworks for a variety of hydrogeological applications.

TOPSOIL – GROUNDWATER SALINIZATION AND – MANAGEMENT WITHIN CLIMATE CHANGE

Nico Deus, Tim Hartmann, Eva González, Jörg Elbracht

Topsoil has been an EU project, funded within the scope of the Interreg North Sea Region Programme 2014-2020, with a focus on the effects of climate change on the groundwater regime. The main goal during the project duration from 12/2015 until 12/2021 was to strengthen the resilience of the north sea region on these effects.

The LBEG as geological survey of Lower Saxony focused on changes in the fresh-/saltwater distribution and groundwater retention via Managed Aquifer Recharge (González et al. 2021a). Therefore, a detailed geological model of the quaternary sediments has been set up. The model contains 19 geological units modelled as base layers. In the next step, airborne electromagnetic data (HEM data) (Siemon et al. 2001, Siemon et al. 2013 & Siemon et al. 2017) were integrated to model the compression zone of the Saalian age Lamstedt push moraine. Several clayey to silty slices could be identified and modelled based on the HEM data. Afterwards, HEM data and groundwater analysis were combined to model the fresh-/saltwater interface within the study area (González et al. 2021b).

A groundwater flow model was built up based on the geological model to evaluate the impact of the climate change (considering sealevel rise, changing groundwater recharge rates & future development of water demands) on the groundwater system, especially the fresh-/saltwater distribution. In the second project part, the effect of seasonal Managed Aquifer Recharge (MAR) on the water budget and the fresh-/saltwater distribution has been analyzed. We used a small scale 2D-flow model, trying to reproduce the geology in a very detailed way and run several combinations of recharge time and water amount. The result showed several positive aspects of injecting rainwater or fresh drainagewater. Sustainable water availability in dry periods as well as the seaward push back of the fresh-/saltwater interface are an important contribution towards a climate adapted groundwater management.

González, E., Deus, N., Elbracht, J., Siemon, B., Steuer, A. & Wiederholt, H., 2021a. Modellierung der küstennahen Grundwasserversalzung in Niedersachsen abgeleitet aus aeroelektromagnetischen Daten. Grundwasser – Zeitschrift der Fachsektion Hydrogeologie. https://doi.org/10.1007/s00767-020-00472-w.
González, E., Deus, N., Elbracht, J., Rahman, M. A., & Wiederholt, H., 2021b. Current and future state of the groundwater salinization of the northers Elbe-Weser region. Grundwasser – Zeitschrift der Fachsektion Hydrogeologie. https://doi.org/10.1007/s00767-021-00496-w.
Siemon, B., Voß, W., Kerner, T. & Pielawa, J., 2017. Technischer Bericht Hubschraubergeophysik Hadelner Marsch Mai/Juni 2004 (Revision 2017). BGR-Bericht, Archiv-Nr. 0134290, Hannover.
Siemon, B., Voß, W., Röttger, B., Rehli, H.-J. & Pielawa, J., 2001. Forschungsvorhaben „Detaillierte aerogeophysikalische Landesaufnahme“ (DAGLA), Messgebiet Cuxhaven, Mai 2000 (Revision 2013). Technischer Bericht, BGR-Bericht, Archiv-Nr. 0131409, Hann.

MODELLING, FAST AND SLOW: HOW TO COMPLETE A LONG-TERM MODELLING PROGRAM

Jan Stafleu, Jan Gunnink, Denise Maljers, Michiel van der Meulen

In 2006, TNO – Geological Survey of the Netherlands initiated the GeoTOP modelling program, aimed at constructing a detailed, national 3D voxel model of the near-surface. GeoTOP schematizes the near-surface in millions of voxels of 100 x 100 x 0.5 m up to a depth of 50 m below sea level. Each voxel contains multiple properties that describe the geometry of stratigraphical units (layers), the spatial variation of lithology within these units as well as measures of model uncertainty. The addition of physical properties to the voxels enables the deployment of the model for a wide range of applications that benefit society.

GeoTOP currently covers about 70% of the total land surface area. In 2020, GeoTOP became part of the Key Registry of the Subsurface (BRO), which led to an increase in the use of the model. In addition, there is a strong demand for GeoTOP in the areas that still have to be modelled. In this presentation, we will look at different strategies to reach national coverage as early as possible while maintaining the quality required by the BRO.

Modelling, Slow – In the last 16 years, modelling was carried out in twelve large model areas, roughly corresponding to the Dutch provinces. Following the completion of the seventh model area in the south of the country (we presented this model at the Bern 2019 meeting), we re-modelled the existing model of Zeeland in order to meet the new quality requirements of the BRO. It takes about three years to build or rebuild a single, province-scale model area.

With five more model areas to go, we may expect to reach national coverage not much earlier than in 2036. This is considered far too late by many stakeholders.

Modelling, Fast – Last year, we took a different tack and created a relatively small GeoTOP model of the municipality of Almere. This city is currently planning the development of some 30,000 new homes as well as a new road and rail connection to Amsterdam. GeoTOP is key to successfully address Almere's subsurface challenges such as soft soils and land subsidence, water management, and thermal storage systems. Because of the smaller area, we were able to build the model in a single year, responding much faster to the needs of the municipality.

Modelling, Fast and Furious – However, modelling the remaining 30% of the country in many small areas does not bring national coverage any closer. We have therefore designed a plan to model the remaining part in a single, large model area in only three years' time. We can do this by focusing on the modelling of those stratigraphic units that are most important for the application of the model in the built environment. In addition, we have set up a permanent team dedicated to the modelling.

After national coverage is reached, the lessons learned from Almere will be applied to update small areas incorporating new data and insights. These local updates may also have a higher resolution and additional properties to meet specific user requirements.

H3O: THE LEGACY OF A DECADE OF CROSS-BORDER 3D GEOLOGICAL MODELLING

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The sustainable management and use of natural resources in border regions requires unambiguous geological information from neighbouring countries. However, the available data often lack compatibility and the same level of detail across borders. After stakeholders in the Netherlands and Belgium had expressed a wish to harmonize the (hydro) geological models in the shared border region, in 2012 the first H3O project was initiated. Since then, H3O projects have focused on a series of adjacent border areas, of which the latest (H3O-De Voorkempen) was completed in early 2023.

Aim of the successive Dutch-Belgian H3O projects was/is to produce consistent cross-border, up-to-date, three-dimensional geological and hydrogeological models of the Cenozoic deposits. Existing geological data (boreholes, well logs, seismic data, fault traces, geological maps and models) were inventoried and collected, re-interpreted according to a harmonised lithostratigraphic scheme and fed into 3D modelling workflows.

The deliverables of each project include: (1) a correlation scheme between the relevant Dutch and Belgian/Flemish geological and hydrogeological units; (2) a consistent fault model of the project area (if applicable); (3) geometrically and stratigraphically consistent geological and hydrogeological models of the Cenozoic deposits across the Dutch-Belgian border. The models represent a state-of-the art reference for the geological and hydrogeological structure of the project areas and provide a base for joint cross-border subsurface management. It is foreseen to fully integrate the models within the national/regional reference models. Furthermore, the correlations between the Dutch and Belgian/Flemish subsurface units may serve as guidance for future cross-border projects. Plenty of new insights from new correlations and revised interpretations have already catalysed discussions and revisions within both national lithostratigraphic scientific communities.

This presentation will present new results from the project H3O-De Voorkempen, as well as reflect on our experiences, impacts and lessons learnt from a decade of cross-border modelling.

The Dutch-Belgian H3O projects are carried out by a partnership between TNO – Geological Survey of the Netherlands, VITO and the Geological Survey of Belgium. H3O-De Voorkempen received support from the Flemish Bureau for Environment and Spatial Development (VPO), Flanders Environment Agency (VMM), Province of Noord-Brabant and drinking water company Brabant Water. The H3O models are available in the public domain via the online data portals of DOV (Databank Ondergrond Vlaanderen) and DINOloket (Data en Informatie van de Nederlandse Ondergrond).

SESSION 2:
SUSTAINABILITY – GREEN TRANSITION

In order to accelerate the deployment of green energy solutions like geothermal energy, hydrogen storage, and carbon capture storage, geological models covering the mid-deep subsurface are required at different scales for different purposes. These models can provide input to territory-wide models that for example evaluate total storage capacities or available geothermal heat, regional models that evaluate dissipation of pressure due to CO_2 injection, or local models that simulate extraction of heat or the migration of a CO_2 plume at a specific location. In this session we invite presentations concerning geological models of the mid-deep subsurface targeting acceleration of the green energy transition.

MID-DEPTH BASIN MODEL FOR SUSTAINABLE SUBSURFACE USE: 500+ M THICK SALT, LEGACY OIL AND GAS, HOT-DRY ROCK AND GEOTHERMAL RESOURCES IN POROUS MEDIA ALL IN ONE PLACE – A CASE STUDY FROM NW POLAND

Zbigniew Małolepszy, Ewa Szynkaruk

Mid-depth regional model built for the central-northwest part of Poland (Gorzów block) [1] is an example of stacked resources comprising, from bottom to top:

- Rotliegend (Lower Permian) volcanics presumably considered as hot-dry rock geothermal resources,
- Upper Permian hydrocarbon traps – legacy and under exploitation, offering possible CO2 storage space or other unconventional use,
- Thick Upper Permian (Zechstein) salt in domed but otherwise relatively undisturbed salt pillows for potential storage of heat or energy carriers.
- Mid-temperature Mesozoic geothermal reservoirs down to ca. 2000 m bsl.

Tapping into the high number of legacy oil-and-gas seismic and borehole data offered an opportunity to construct a well-constrained 3D regional model, with added advantage of linking it – within the GeoERA framework – to the Brandenburg state model across the border. The resulting parametric grid allows informed screening for unconventional resources and provides a rigorous starting point for managing use conflicts and synergies.

Planned analytical extensions to web model viewer (https://geo3d.pgi.gov.pl/en/project/3d-geological-model-gorzow-block) will provide tools for more thorough exploration of modelling results, and disseminating raw model files through National Geological Archives ensures efficient re-use of data compliant with FAIR principles.

[1] Szynkaruk E. (red.), 2020. Trójwymiarowy, cyfrowy model pokrywy osadowej bloku Gorzowa – opracowanie końcowe [3D digital model of the Gorzów block – final report]. National Geological Archives, PGI-NRI, Warszawa, Poland.

SEEMS DEEP – GEOPHYSICS BASED 3D GEOMODELING FOR MINERAL EXPLORATION

Suvi Heinonen, Jochen Kamm, Tuomo Karinen,
Tuomas Leskelä & the SEEMS DEEP working group

In the project SEEMS DEEP, we are developing geophysical methodologies for deep imaging of the bedrock for mineral exploration. The test area of the project is the Koillismaa area, Finland, that provides a full-scale natural laboratory with geophysical anomaly that has been of interest for geoscientist several decades. This anomaly is a 50 km long zone connecting the distant parts of the same mafic intrusion, and it is observed with gravity, seismic reflection and AMT surveys. The recent drilling of 1700 m long diamond drill core has confirmed that the anomaly reflects the presence of 2.45 Ga mafic-ultramafic intrusions. The deep borehole has detailed geological and geophysical logs suitable as prior constraints to inversion and interpretation that lead to 3D geomodel. The rocks of the age group of the intrusion are very potential for several commodities included in the EU critical material listing. We aim to improve the deep exploration success date in order to supply the raw materials needed for the energy transition and especially for the battery industry, and 3D geomodels provide a means to visualize results of various surveys also in a form understandable for wider audience.

Petrophysical data analysis provides links between different physical rock properties and lithologies which need to be understood in order to conduct successful geophysical imaging or geomodeling.

The background petrophysical data from Koillismaa region include density, magnetic susceptibility and remanence, seismic P-wave velocity and galvanic specific electrical resistance measurements from drill core samples. Low-fold seismic and sparsely sampled AMT measurements indicate high acoustic impedances and elevated electrical conductivity values, respectively, of the ultramafic rocks at depth. We have created a 3D geomodel based on the petrophysical data analysis and available data set. This model will consist of surfaces representing the lithological contacts, fracture zones, dikes and faults and ultimately it will be converted into a volumetric model populated with interpreted rock-physical properties. The geomodel is currently used for geophysical modelling and inversion of synthetic seismic and EM/ERT/IP data. These simulations will facilitate optimized survey design for the large field data acquisition campaign planned for autumn 2023. Later the results of new geophysical measurements are used to improve the current geomodel.

Koillismaa geomodel aim to facilitate strategic drilling, which means that roughly 20-50% less exploration drill holes will be needed to achieve sufficiently detailed characterization of the deep geological environment or 3D delineation of the ore hosting rock units. To reduce the number of exploration drilling during the exploration phase, geoscientists need to limit the geological uncertainties with more reliable geophysical data, which leads to more reliable 3D geomodels.

MAKING THE DUTCH 3D GEOMODELS SUITABLE FOR THE ENERGY TRANSITION – CHALLENGES AND SUCCESSES FOR GEOTHERMAL ENERGY

Johan ten Veen, Denise Maljers, Hans Veldkamp, Andreas Kruisselbrink, Anuska Kaliar (TNO – Geological Survey of the Netherlands)

ThermoGIS is a public, web-based geographical information system that contains depth, thickness, porosity and permeability and temperature maps of many potential aquifers in the Netherlands. These property maps are used to calculate the most important outputs of ThermoGIS which are geothermal potential maps of the Netherlands that can be consulted in a map viewer. The ThermoGIS workflow consists of several steps of which the three most important ones are: (1) modelling aquifer geometry; (2) estimating aquifer properties and temperature; and (3) incorporating technical and economical parameters. This presentation focuses on the aquifer modelling.

ThermoGIS builds upon the nationwide 3D DGM-deep model that includes 13 stratigraphic levels that represent the (near) bases of the Palaeozoic, Mesozoic, and Cenozoic lithostratigraphic units. This model is based on seismic interpretation and well data and supported by biostratigraphy. It does not contain information on individual saline aquifers. To incorporate these aquifers a workflow is developed to model the depth and thickness of all aquifers that reside within the DGM-deep units by using information of nearly 4000 wells. All aquifers within a DGM-deep unit are modelled with respect to the base of that unit, making ThermoGIS and DGM-deep fully consistent. This consistency is not obvious as the number of wells used for ThermoGIS is considerably higher than that used for the calibration (well-tying) of DGM-deep. Therefore, a reiterating process is employed in which the bases of the aquifers are derived by interpolating the difference between base of the aquifer from well data and base of the group-level grid and adding it to the latter. Subsequently, the interpolated thickness is added to obtain the top of the aquifer. Multiple aquifers are stacked between groups' base and top and intersections are corrected for. The interpolation process is assisted by polygons demarcating the aquifers' spatial extent. These polygons have thickness values assigned that can be used to steer the thickness at pinch-outs and faults. The aquifer thicknesses are stochastically modelled using kriging and the resulting kriging variance which represents the thickness uncertainty is used to calculate P10 and P90 thickness maps.

Each modelled aquifer is populated with vertically averaged well porosities and -permeabilities. Subsequently, the heat in place (HIP) is calculated by using these flow properties, net thickness of the aquifer and its temperature. In a next step, technical (doublet) and economical parameters are incorporated to derive the technical and economic potential and the potentially recoverable heat.

In the future, ThermoGIS will also focus on shallow geothermal energy and heat storage for which the shallow aquifers of the hydrogeological model REGIS II need to be incorporated. This model includes Neogene aquifers and uses the geological DGM-model for the shallow subsurface as a basis.

CONSTRUCTION OF A PROVINCIAL SCALE 3D GEOLOGICAL MODEL OF THE WESTERN CANADIAN SEDIMENTARY BASIN IN SASKATCHEWAN, CANADA

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3D geological models are becoming an important asset for geological surveys for addressing societal challenges of sustainability and climate change. Solutions to these challenges, including initiatives such as searching for critical minerals, subsurface storage, and geothermal potential all benefit from the characterizations of subsurface geometry that 3D geological models provide. In collaboration with the Saskatchewan Geological Survey, the Geological Survey of Canada engaged in the construction of a provincial scale 3D geological model of the Western Canadian Sedimentary Basin (WCSB) in Saskatchewan with the intent to model the entire basin in the future. The basin hosts many resources such as critical minerals (e.g. lithium, helium, potash) and is targeted for deep CO2 storage, groundwater, and geothermal applications. The model can serve as a knowledge layer for these applications as well as for 3D mineral prospectivity mapping. The dataset for the 3D WCSB geological model in Saskatchewan consists of approximately 142, 900 formation top and unconformities markers interpreted from about 11, 900 oil and gas wells. The dataset sampled 49 units from the Phanerozoic sedimentary basin, 7 major regional unconformities and the undivided Precambrian basement.

The 3D geological model was constructed in Gocad/SKUA geomodelling platform using a hybrid implicit-explicit approach. The model was constrained using the stratigraphic markers along with available geological knowledge including the bedrock geology map and previously interpreted subsurface areal extents of the units. Challenges related to modelling using vast amounts of data and strategies for tackling provincial scale modelling efforts are presented. The constructed model can provide valuable information for applications previously mentioned including formation thickness and depth, relations with adjacent formations or unconformities. In addition, the model can be used for model validation for ongoing development of other geological modelling methods. Finally, collaboration with the provincial survey was critical in constructing stratigraphically coherent and geologically validated model and important for future work in modelling the entire basin across four other provinces and territories.

SESSION 3:
MODEL DISSEMINATION AND DATA MANAGEMENT

As Geological Surveys and private contractors keep modelling, geological models become larger and more detailed with more features and attributes. How is the resulting knowledge managed? Do you follow any specific standard, for example the FAIR principles to make geological models Findable, Accessible, Interoperable, and Reusable? Here, we invite presentations focusing on use cases and working solutions where geological models contribute to a sustainable future for society.

3D MODELS AS A BRIDGE BETWEEN SCIENCE AND POLICY

Abigail K. Burt and Riley P.M. Mulligan

Recently, the Ontario Geological Survey (OGS) formed part of a multi-disciplinary team tasked with creating a defensible boundary around an 80 km long section of a complex glacial moraine system being considered for environmental protection. This task provided the OGS with the opportunity to become our own clients and use our products to answer land use planning questions.

Publicly accessible (and free!) data from the OGS included seamless maps of surficial geology and sediment thickness, bedrock topography and geology, and areas of karst. Published groundwater resources studies comprising a 3D model and derivative products cover the northern and southern, but not the central, portions of the moraine. GIS and Google EarthTM versions of structural and isopach maps for each model layer, a subsurface database, interpreted logs, photos and analytical data for all cored boreholes, high-resolution plates of prepared cross-sections and a detailed report are found within each study. Cross-section viewers designed to display and save user-defined vertical slices through the 3D models no longer function, but we were confident our products would still satisfy the request.

It quickly became apparent that team members lacked the geological expertise needed to use the information we provided. Our maps and 3D models convey a wealth of information to other geoscientists but were either incomprehensible to the team or did not easily integrate with other ministries' data. When we outlined proposed planning boundaries, it was difficult communicating the reasoning behind those boundaries. Many basic (to us) geological concepts required leaps of imagination for our collaborators: the moraine is composed of many component landforms, displays rapid changes in sediment texture, thickness and architecture, and is variably connected to multiple regional groundwater flow systems.

Our products were not suitable for communicating these concepts to non-subject matter experts – but this was a tremendous learning opportunity. We are learning to communicate core knowledge first and then slowly build on this foundation. We are working on a new 3D model cross-section viewer, new derivative maps, and finally, we have seen the power of getting non-experts out of the office and into field.

GEUS 3D DATABASE
PRESENT STAGE AND WHAT DID WE LEARN

Marianne B. Wiese, Christian Brogaard Pedersen

We would like to present GEUS 3D database, where geological 3D models produced in different modelling tools of all scales and geometries can be archived. So, 3D models are archived in a common format, that may be read also in the future, when original model-files may have become outdated.

The development of GEUS 3D database has been coordinated with the development of the 3D database for the European Geological Data Infrastructure. The EGDI 3D database is a common facility for the european geological surveys to make their 3D models available for the public and the two databases share their data model and routines.

Along with the 3D database itself, an application has been developed to show whatever is stored in the database. Besides giving other geologists and consultants the opportunity to find and acquire existing geological models for re-use, this viewer application gives a broader audience an accessible version of current geological knowledge.

GEUS 3D database archives local models and as of now 2 national models. One of the national models is of the deep underground and the geological units important for the utilization of geothermal energy. The second national model is of shallow hydrogeological layers and is used, among other purposes in the management of groundwater in Denmark.

3D VISUALISATION OF GROUNDWATER QUALITY AND GROUNDWATER QUANTITY CONTRIBUTES TO SUSTAINABLE PLANNING AND PROTECTION OF GROUNDWATER

Mariëlle van Vliet 1, Hans Peter Broers 1, Willem-Jan Zaadnoordijk 1, Wilbert Berendrecht 2
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A good understanding of groundwater systems is essential for weighing different interests relating to human uses that depend on the water resources. The Roer Valley Graben (RVG), a Dutch, Flemish and German transboundary area, contains an important aquifer system that is crucial for many uses, including drinking and industrial water supply and heat storage, as well as playing a role in the conservation of terrestrial and aquatic ecosystems. In H3O-PLUS, which is part of the Horizon2020 funded GeoERA RESOURCE-project, 3D visualisation of transboundary patterns of measured groundwater quality and groundwater heads has been realised, contributing to improved sustainable planning and protection of groundwater.

Two groundwater viewers were developed, one for groundwater quality and one for groundwater heads, bringing cross-border groundwater data together. In these viewers, the cross-border (hydro)geological 3D models were merged and subsequently used for interpretation purposes, relating groundwater properties to the subsurface hydrogeological structure. For example, water quality problems in eastern North Brabant, the Netherlands, can be visualised by showing the concentrations of various hydrochemical parameters (e.g. nitrate, sulphate, oxidation capacity) relative to the shallow Beegden and Sterksel Formations and the deeper Peize/Waalre and Kieseloolite Formations. The concentration differences between the formations can be analysed on maps, in cross sections and in different types of graphs.

Due to deterioration of water quality over the depth range of the formations mentioned, abstractions for drinking water supply were shut down or moved towards deeper aquifers in the Peize/Waalre and Kieseloolite Formation in the RVG. The increase in abstractions in these aquifers contributed to the decrease of groundwater heads, which is now visualized visible using the groundwater quantity viewer. This tool enables the easy identification of temporal trends in groundwater heads for individual observation wells. Moreover, the tool allows for aggregation of trends over larger areas, depth ranges and/or geological Formation are and visualizing them maps and cross-sectional views.

The two viewers enable the interactive viewing of hydrochemical and hydrological information in relation to the hydrogeological structure of the subsurface. By using the cross-border harmonised (hydro)geological models, this is even possible across national borders in the Roer Valley Graben groundwater system. Combining information from both the quality and quantity viewer, the tools enable establishing interdependencies between groundwater quality developments and quantitative water trends, thus supporting integral sustainable management and protection of the resource.

RESOURCE was part of the GeoERA program and has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

OBTAINING A SOCIAL LICENSE FOR GROUNDWATER ABSTRACTION AT KURIKKA AQUIFER, FINLAND USING A COMMUNITY ACCESSIBLE HYDROGEOLOGICAL DATA AND SOFTWARE PLATFORM

Niko Putkinen, Ben Wood, Holger Kessler

Groundwater has a strategic importance in Finland, especially in western coastal areas that lack large groundwater bodies. The city of Vaasa is the capital of Ostrobothnia and struggles with sufficient access to clean drinking water, which is largely sourced from surface water. After the discovery in 2010 of a large buried valley aquifer system in the Kurikka region and from 2014 onwards research in the area is conducted in the collaboration the Water Services Public Utilities of Vaasa, (Vaasan Vesi), the Water Services Public Company of Kurikka, (Kurikan Vesihuolto OY) and Centre for Economic Development, Transport and the Environment in South Ostrobothnia (Etelä-Pohjanmaan ELY-keskus) and Geological Survey of Finland (GTK).

Geological surveys in the region have proved hydrogeological units interlink between bedrock faults, fractures and other structures, the topography of the bedrock surface and glacial deposits above. Buried valley aquifers are connected to high standing groundwater recharge areas covered by sands and gravels formed under the shoreline processes. The 50 - 100 m deep bedrock palaeovalleys are filled by multiple thick sand and gravel beds (aquifers) with till (aquitards) between them, and a marine clay/silt deposit forms an impermeable cap for the aquifer system. Due to the hydrogeological setting and the long route from the recharge area to the valley bottom the clean groundwater circulation and storage is big enough for Kurikka and Vaasa cities.

Meanwhile, the region of Kurikka is an important agricultural centre in Finland, due to a presence of clean and sustainable groundwater resource. A wide variety of agricultural products come from here, including organically grown produce. The local community have a strong connection to, and deep pride in their natural environment. Water is important for everybody and geologists need to convince people that extracting groundwater is safe and sustainable. So, the future challenge for the water companies therefore is not water treatment, but to demonstrate to the local communities and landowners that large water use and drawdown of groundwater will not adversely affect the local environment.

To assist with this, the Geological Survey of Finland have developed the concept of an accessible web system which will enable geoscientists and stakeholders to interact with the data and the model. On the backend, this system will store large volumes of time-series downhole water logger data ready for query, and support rapid queries into that data by location and by time via an API. In the user interface, the system will display live and historic groundwater level monitoring data in boreholes, cross-sections and maps, putting the data in context with real world geological features. The system will link to work done in collaboration with the British Geological Survey using the Groundhog software, which contains a useful modelling engine, and is now open source. The system API will be made compatible.

HEADING TOWARDS INTEGRATION OF 3D DATA FOR MUNICIPALITIES – GEOCIM TRIAL FOR LIBEREC CITY

Zita Bukovská, Jan Jelének, Lucie Koucká, Ondřej Švagera

With growing demand for underground use in urban development, the lack of knowledge about an underground arises as a significant problem in some areas – typically cities with long history. The development and usage of a 3D modelling with ongoing cooperation between the City of Liberec and the Czech Geological Survey led to a pioneering project on "geological" near-surface city information model of small testing area within Liberec city centre.

The general idea of the project was to establish urban underground 3D data exchange between geological surveys and cities which will be supported by development of 2D and 3D data visualization and exchange platform. Such model should give full power to the municipalities to display all underground data provided by the geological survey and work with them on daily basis. 3D model of a city should comprise all available archive data, together with new interpretation of such data. It should also feature important engineering networks, such as sewage system, water and gas pipelines or historic underground structures. Revealing the conflicting natural and man-made elements helps to make city management and urban planning safer.

Data available in archive of the Czech Geological Survey (boreholes, geological maps etc.), Museum of Northern Bohemia (underground works etc.) and the City of Liberec (data from urban planning department) were pre-processed and integrated together with modelled geological structure based on geological expertise and modern history findings. The 3D geological model was built in MOVE software with high stress on near-surface in order to show possible spatial interactions of man-made structures with water level, tectonic faults and other potentially problematic objects.

In order to allow the local municipality to use the 3D model a QGIS-based environment was used to prepare a license-free 3D environment with a possibility to obtain subsurface data directly at a specific point. These data are derived from the meshed 3D model into planar point-based grid , which can be easily opened by urban planners in GIS software.

In scope of these topics in cooperation with colleagues from Norwegian geological survey – supported by the Norway Grants – promotional video on this topic was made to raise public awareness and knowledge on underground.

SESSION 4:
ADVANCES IN RESEARCH, TRENDS AND INNOVATION IN HONOUR OF KEITH TURNER

The field of 3D geological modelling is broad and covers multiple aspects of relevance for the creation of sufficient geological models. Keith Turner, who sadly passed away in 2022, was a prominent figure within the research and innovation in 3D geological modelling. In honor of Keith Turners work, this session focuses on the recent research, fundamental or applied, of methodologies, modelling concepts, field data acquisitions, geological interpretations, process modelling, implicit and explicit modelling, handling of uncertainties, etc.

THE IMPORTANCE OF MEMORY AND LISTENING TO STORIES

Holger Kessler

This presentation in memory of Keith Turner will demonstrate the value he has brought to me, the wider profession and community by remembering historic events and importantly communicating about them. I will try and illustrate that even though technological progress seems to change everything we do at an increasingly rapid speed it is wise to listen to the previous generations and draw on lessons that have been learnt before and build a more diverse and informed picture of our world.
Keith was famous for remembering a lot of detail and talking about events and developments over a long period of time at length - his passion to improve the future were always linked to a rich understanding of people, historic developments and importantly trying to not repeat mistakes and re-invent wheels.
I will share two artefacts that Keith made sure are now preserved for prosperity from the pioneering days of digitalisation, productisation and marketing at the British Geological Survey in the early 1990s. These comprise of a 10 minute film, rescued from a VHS tape a result of Keith's memory, connections and tenacity and a series of reports and notes sent to me by post in the mid 2000s that contain unpublished and very nearly lost learnings about BGS' baby steps into insurance products and financial markets.
The take away lesson is to learn from the past, to listen and respect our recent ancestors (even if painful and repetitive at times) and importantly to follow Keith's exemplar to try and remember the past, tell stories and care about progress and the future.

FROM FIELD DATA TO 3D MODEL OF DEEP UNDERGROUND ENVIRONMENT, MULTIDISCIPLINARY APPROACH AND DATA INTEGRATION FOR FUTURE DEEP GEOLOGICAL REPOSITORY

Ondřej Švagera, Zita Bukovská

During the search for suitable Deep Geological Repository (DGR) site in the Czech Republic an experimental program is being conducted in the environment of former uranium mine 500 m below ground. Czech Gelogical Survey have been studying the surrounding metamorphic crystalline rock since initiation of excavation works approx. 10 years ago. In that time, our approach to field data collection has changed significantly and the need for comprehensive 3D models is more pronounced than ever. Czech Radioactive Waste Repository Authority (SÚRAO) has assembled a large group of experts from the private and academic sectors to provide necessary data to characterize the Underground Research Facility (URC) and consequently conduct experiments and monitoring program. The common goal is to detect and describe brittle structures such as faults and joints as these are a major concern in safety assessments. This collaboration has resulted in various aquired data such as geophysical profiles, groundwater inflows, seismic tomography, stress field orientation and geotechnical characterization of excavated galleries. We would like to show that by including photogrammetric and LIDAR scanning we can accurately place in-situ measurements and moreover use these in order to build as accurate 3D geological, discrete fracture network or hydraulic models as possible.

UNCERTAINTY ASSESSMENT OF EXISTING 3D GEOLOGICAL MODELS

Ingelise Møller, Frederik A. Falk, Rasmus B. Madsen, Peter Sandersen, Anne-Sophie Høyer

Uncertainty assessment is an important part of the 3D geological modelling process regardless if the output of the modelling is a cognitive model or a stochastic model. Reuse of existing 3D geological models is common; however, an uncertainty assessment may not have been carried out or lost.

A procedure for evaluating the uncertainty of existing geological or hydrostratigraphic models is presented. The need for such a procedure emanates from work on uncertainty assessment of the National Water Resources Model for Denmark, the "DK model". The hydro¬stra¬tigraphic model, used by the DK-model is constituted by multiple models made by different consultants during the Danish groundwater mapping campaign. Due to differences in economy, prioritization, modeller skills, amount and quality of data, geological complexity etc., the quality of the models varies significantly. Therefore, a procedure assigning point-specific uncertainties to each layer in this hydrostratigraphic model is developed, where all the relevant sources of information about the subsurface available at the modelling time are considered.

The main sources of information are the national databases for geological and hydrological information, Jupiter, and geophysical data, GERDA. Furthermore, information on model and borehole quality have been incorporated to guide the uncertainty evaluation. Simple quality assessment of the lithological borehole information and depth dependencies are used quantifying borehole standard deviations whereas resolution, footprint and penetration depth estimate of available geophysical data are used quantifying standard deviations of each type of geophysical data. The lateral extent of the information from a given source of information will be controlled by the geological complexity at the given position.

The point-specific uncertainties will be used to define an interval, where the models might differ from the original static model and subsequently produce an ensample of geostatistical realizations within the estimated standard deviations.

BUILDING ON 50 YEARS OF GEOMODELLING: WALKING A TIGHTROPE BETWEEN TRADITION AND CLEAN SLATE

Nicolas Clausolles, Thomas Janvier, Simon Lopez, Laure Pizzella, Nicolas Gilardi, Amaya Fuenzalida, Théophile Guillon, Léana Quimerc'h

Geological surveys are facing the transition from systematic 2D mapping of national territories to more versatile – possibly cross-border – 3D models. BRGM has produced geological models for several decades in a project driven approach implying specific goals, hypotheses, scales, modeling tools... In such an approach, a few experts' choices may constrain the final deliverable and hamper interdisciplinary contributions. BRGM is currently redesigning its set of existing tools into an open modeling platform based on modular software components. This is an opportunity to take stock of our vision of 3D geological modeling, the way we produce and make use of geological models, and to rethink the way we want to work tomorrow. In this talk, we will share some of the challenges that we are currently facing in this redesign. A first observation is that the era of monolithic software is over. As a geological survey, we need to find our position – both individually and collectively as European surveys – between two major trends: the replacement of proprietary commercial suites by web-service based cloud platforms and the rise of many open-source initiatives. Though promising, the latter does not benefit from a mature structured global community support yet, as it can exist in other communities (e.g., for GIS), which would make us take the next step. Another observation is that there is still a considerable gap between the geologist's dream tool and the modeling experience that geological software have been offering for the last twenty years – mainly consisting in popularizing the "implicit" modeling approach. Ideally, new tools will combine both proven legacy and newer methodologies to overcome existing tools limitations and promote true interdisciplinary experience. Though some fields of research are promising, as are many technological devices, the feeling is that we still need a breakthrough that would change the daily life of geological model producers and represent a clear alternative to old monolithic software. Finally, the major challenges that the geomodelling community is facing are probably the ever-increasing complexity and diversity of uses of geological models. We want tomorrow's models to be detailed and accurate, upgradable and scalable, to allow for uncertainty quantification and risk analysis, etc. Finally yet importantly, we also want to share these models across domains and applications. Meeting all these needs requires us to rethink our definition of a geological model. Observing that several tools share common core concepts (e.g., geological pile/architecture to express relations between geological interfaces), a first step is to clearly identify and harmonize these underlying concepts. This will pave the way to their generalization and to the emergence of a common definition of a geological model as a framework for interdisciplinary contributions.

STRUCTURAL MODELING WITH GEOCOGNITIVE PROCESSES

Imadeddine Laouici, Christelle Loiselet, Gautier Laurent, Yannick Branquet

This contribution introduces a geocognitive approach to the process of structural modeling based on expert's knowledge. This process is a dialogue between data interpretation and numerical representation, where different experts put together their knowledge and expertise to represent at best how they conceptualize the geologic reality. Existing modeling systems give experts substantial assistance in parameterizing and realizing their conceptual understanding of geologic architectures. However, these systems intensively rely on experts to understand and interpret these architectures especially when using spares data like wells and field observations. this is because they are conceived with a focus on resulting information and not in the entire knowledge and mechanisms behind the interpretation. The proposed approach is inverting this paradigm of modeling through the automation of the conceptualization processes based on expert's knowledge. In this approach, expert's knowledge is formalized by the mean of a semantically rich knowledge model in a human-machine readable format (ontology). This knowledge includes aspects about geometrical characteristics of geological features (objects and structures) in combination of relevant contextual geological aspects. Relationships between these features and the multiple types of modeling inputs and modeling operations are also highlighted in the knowledge model. To use this knowledge model, we propose a comprehensive structuration of the modeling operations. We give particular interest to the interpretation phase, in which we simulate how experts proceed in their interpretations, e.g., how they select data, how they interpret these data and confirm their interpretations, and how they upgrade their prior knowledge. Based on the preliminary results on synthetic data, we argue that this knowledge-based paradigm is effective as it requires less human interplay and does not necessitate resting on large initial datasets. Also, it opens new avenues for exploring structural uncertainties related to geological knowledge.

MAKING GEOSCIENCE DATA AND INFORMATION MORE ACCESSIBLE IN URBAN ENVIRONMENTS

Steve Thorpe

The BGS has a collection of over a million UK borehole records held in the National Geoscience Data Centre, and thousands of new ground investigation records are added each year. This data provides vital geological, geotechnical and geoenvironmental information that is essential for construction, infrastructure and academic research particularly in urban areas where the majority of the boreholes are drilled. However, the BGS estimates that 80% of borehole data is not reported to them, resulting in an estimated loss of data and knowledge to the UK economy valued in the region of £150-200 million per year.
There are several BGS-lead initiatives to help address this problem such as 'Dig to Share' and 'Big Borehole Dig' project which work with the industry to change the culture around data sharing. The BGS has also put in place data sharing agreements with organisations, like Network Rail, Environment Agency and the Welsh Government, committing them, and their contractors, to provide their ground investigation records to the BGS.
In the last couple of years, the BGS has been working with the UK government to develop standardised clauses regarding ground investigation data that can be used by all public sector organisations. These clauses are now in the latest version of the UK Construction Playbook, which sets out key policies and guidance for how public projects are assessed, procured and delivered. The Playbook should be adopted by central government and arm's length bodies on a 'Comply or Explain' basis.
The use- and re-use of this data means that BGS can offer further products and applications such as the BGS Urban Interactive Model Viewer. The web-based delivery tool links geological, hydrogeological, and engineering geology reports to visualisations of synthetic cross-sections, boreholes and slices derived from the 3D model, providing an entry point to a wide range of BGS literature and data. This is one amongst many applications and delivery mechanisms in which the BGS is engaging with.

ADVANCED 3D GEOLOGICAL MODELLING AT SGU: A VIRTUAL FLY-BY OF KEY MINERAL DEPOSITS IN SWEDEN

Stefan Luth

The Geological Survey of Sweden (SGU) has implemented 3D geological modelling as an integral part of its workflow and geological mapping program. At the department of Mineral Resources, a growing number of geologists have access to advanced 3D geomodelling packages, such as Leapfrog Geo and SKUA-GOCAD. Together with geophysicists and geochemists utilizing interlinked software packages (Geosoft and ioGAS), the survey geologists can now construct highly advanced, multi-scale 3D geomodels to improve geological understanding and to efficiently provide 3D information and interpretations of the subsurface for decision making.

Examples of case studies are presented covering different geological settings and mineralization types throughout Sweden. Starting with the national 3D geological model of Sweden we zoom in on the classic ore district Bergslagen. Firstly, we fly around the currently mined Lovisa Zn-Pb deposit to briefly summarize its geology and to demonstrate the use of XCT-XRF drill core scans in 3D modelling (Luth et al. 2022). We then fly to Riddarhyttan (Fe-Cu-Co-REE) to highlight the strength of combining multiple datasets from 1) historic drilling and mine-maps 2) recent airborne geophysics and geological mapping and 3) very recent drill data provided by the exploration industry. We continue our flight northwards with a pitstop at the Blötberget Fe deposit where SGU conducted a short field campaign combining UAV derived magnetic measurements and geological mapping to investigate if the lateral extend of mineralization is controlled by a fault. A geological model based on 3D seismic data and drill data from the deposit will also be shown here. Our final destination is the western boundary of the Ljusdal lithotectonic unit (central Sweden) along which several structurally controlled gold, cobalt and lithium occurrences are presently targets for 3D geomodelling, with additional data input provided by two universities and other partners.

The common thread in the presented case studies is not only the combination - and partly integration - of multiple datasets acquired for various purposes at different times, but also to go all the way in terms of analysis and geological interpretations while constructing the model. This requires a multi-disciplinary approach, modernization of mapping projects, long term planning and continuity as well as flexibility, and an overall acceptance of the “3D modelling geologist” at the geological survey. Will this approach lead to the abandoning of traditional fieldwork and paper maps? On the contrary, geomodelling demands for a large number of reliable field observations (targeted and untargeted), field measurements and the optimal usage of historic data, including paper originals. Should we be doing this as a national geological survey? Yes, it is our mission!